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Time elasticity - who and what determines the correct project duration?

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Abstract

Management of time and progress is a key element in achieving project success. In a classical time-cost-quality division, determining the correct duration of the project has obvious benefits and drawbacks for cost and quality. Generally, it is thought that cost increases at either end of the duration/time spectrum and similarly, quality is thought to decrease. We describe how the determination of project duration seems to fall between the various perspectives on project management. In a task-perspective, deterministic tools can calculate and predict optimal durations – but is no guarantee for success. In an organizational-perspective, the institutional economic theory may help us interpret the choices made by actors in the project tool chain – and which incentives and processes are needed. However, we present empirical evidence from the Norwegian construction industry, that reality often falls between the theory posited by either view. We propose to examine this span through a concept of time elasticity in between cost and value – where the flexibility and lack of pursuit of pace may be explained through an inherent elasticity in which cost and value is elastic within certain boundaries.

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Keywords: Cost and project durattion, Productivity, Construction Projects;

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1. Introduction

Projects behind schedules is an indicator of poor productivity and bad project performance[1]. Any delay in a project can lead to cost and time overruns and these two are connected[2]. In addition, This delay affects the project by increasing cost, losing competitive advantageous and market share and raise in disputes and claims between involved parties[3]. When projects are delayed, they are either extended or accelerated and therefore, incur additional cost. Delays in construction cause damages to the project and result in conflict and dissatisfaction to all parties involved[1,4]. For the project owner, delay may lead to loss of revenue through lack of production facilities and rentable space or a dependence on present facilities. For the contractor, delay may result in cost overrun due to longer work period or penalties, higher material and labour costs[5,6]. During planning and scheduling the planned duration of construction projects are often fixed through iterations between experience data and figures, and the requirements of the project owner / sponsor. Planning and managing time and progress is a key element in achieving project success, both in terms of the classic time-cost-quality triplet of project management, but also in terms of commercial viability for constructors as well as project owners. It is generally assumed that it is a strong relationship between project's time to delivery and its total costs. For some types of costs, the relationship is in direct proportion; for other types, there is a direct trade-off[7]. According to Kerzneer[8] can the costs associated with the project be categorized as direct costs or indirect costs. The relationship, or trade-off between cost and time is generally thought of a u-shaped curve where the cost increases at either end – i.e. extreme time compression or elongation will usually incur an increase in project cost. When compressing time, i.e. speeding up a project this cost is often referred to as "crash cost" where the actions taken to increase the speed also incurs disproportional additions to cost due to factors such as labour, rework, extra operating equipment or similar. These are commonly seen in during recovery of delayed projects. In the other extreme, working slow may also increase cost where the time-dependent costs (e.g. rig and operating expenses) becomes larger than necessitated by the production and outweighs any savings on production-dependent costs (primarily procurement and labour directly involved in production) (see Figure 1) [8 pp 520].

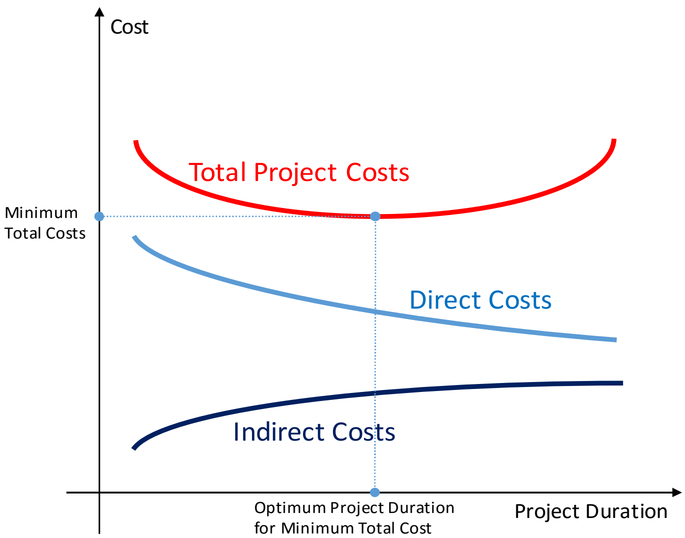

Figure 1 Generic relationship between duration and cost (adopted from [8 pp 520])

Balancing the Time-Cost-tradeoff in the construction phase can be seen as an optimization problem. According to Rolstadås[9] it is usually possible to shorten the duration by adding resources, working overtime, etc. However, this is normally associated with increased costs. The extra costs incurred by shortening the project duration must be balanced against the extra benefit a shorter duration will give. The optimum value is obtained where the marginal cost of acceleration balances the marginal benefit of shorter project duration[9]. This suggest that increasing or decreasing the speed of the project is closely linked to project cost, and that project pace can be changed simply by adding more resources or changing the working schedule.

Time / cost tread of – how does the different stakeholders consider time?

Generally, projects are not delivered in a vacuum[10]. The project is scoped to deliver some results, in order to produce effects for one or more users. They are owned, governed and controlled by an entity and roles that may or not be the same as the user. This is an important distinction, perhaps especially in terms of public projects – where the end-user rarely directly 'foots the bill' for the project. Correspondingly the project owner, or its representatives, may also not be a potential user of the result it is set to govern. We have adopted a division into four roles in this study, as shown in Table 1, adopted from Johansen et al[11].

Table 1 Project Roles, Summarized

Contractor	Project Manager (PM)	Project Owner (PO)	Society / Users
Is hired by owner/manager to execute parts or whole project. Bound by a contractual agreement to deliver whole or part results towards the overall goal of a project.	Project manager acts on behalf of the project owner Is restricted by mandate and delegated resources and authority from project owner. Is responsible for the overall management of a project[12] If the project is sufficient in scope, the manager will have a staff to support the managerial role and activities.	Bears the owner rights and responsibilities of the project[12] Responsible for both cost and income related to the resource (profit responsibility) Assumes the threat related to the cost and future value of the project. Gives residual control rights, and residual profit responsibility[13]. Full right of use, possession and disposal of a resource. Within the legal framework, not necessarily accountable to anyone else[14].	Widely users include everybody who uses the result of the project (the building, hospital, railway line etc.). In a narrow definition, the user representatives. Representatives are not necessarily representative of the average user during the entire lifetime of the final product. Projects usually interact with user representatives, who act on behalf of those who intend to use the project result.

A success is only seldom judged by how optimal it could have been, but rather whether or not it has reached the goals and achieved the effects in its charter. It is important to acknowledge and consider the elasticity in time – throughout the whole value chain. While the owner perspective and the project organisational perspective is often described, the project manager as well as the owner representatives might not share in the values of their organisations. In the organisational-perspective, one could easily find explanations for classical challenges such as delayed decision-making and project duration elongation as a means towards risk-reduction as incentives made at the organisational level, seldom applies directly at the individual level – this "irrationality" is not taken into account during the determination of project duration in the front-end planning and scheduling

On the more abstract level - consulting the literature on *theory of* project management the aspect of Time (and duration) in project theory is treated differently within the various schools or perspectives on project management. The practical methods and tools for planning and scheduling projects stems from what is considered to be a *task perspective* on project management. Lending and sharing methods with related industrial management, applied mathematics and "scientific management". This lends well to a sequential theory of planning, execution and evaluation[15]. Easily and often critiqued in that the theory and methods even when followed to the letter – does not guarantee success nor avoid failures. Sometimes held up as the alternative approach, the organizational perspective on project management stemming from social-technical sciences traces several aspects (such as process, governance, behavioural, cultural and political) and studies how these affect and impact projects[16,17]. The application of economic theory on governance and behavior is not uncommon, including well known examples such as Principal-Agent Theory[18] and Transaction Cost Economics[19]. In economic literature, price elasticity of demand is defined as a measure of how demand responds to price[cf. 20]. Price elasticity concepts is also well established in transport model /transport economic theory[21]. This type of models tries to predict how people will change their travelling routines/habits if the price of petrol, parking, toll boots or the time in que increase, compared to spending more of daily travel time on public transport. The idea behind this model is that peoples travel habits are more or less value driven. Some will choose public transport because is the quickest or the cheapest solution. Some will choose it because they consider it as more environmentally friendly and some will only choose public transportation as alternative when commuting with car only is more or even a lot more expensive then the public alterative. So if a society wants more people to use public transport – can they lower the price on the bus or train, or they can decrease the travel time on the public alterative, or they can make the alternative commuting with car more expensive or restricted. The price elasticity models help society to decide which measures shod be use. We believe that similar behavior and logic to some degree exists in projects. When the different stakeholder negotiates the project duration it not only at cost time problem, we suggest that different stakeholders interest in the "value" of speeding up or delivering late play important part when a project pace is determined. We will in this paper argue that this generic relationship presented in Figure 1, is too simple and that value of speeding up or slowing down a project pace is dependent on how elastic the project as technical system and how elastic it is in terms of delivered value. The following research questions has guided our study:

"Who will get increased or decreased value if the project is deliver at a slow or fast pace – and conversely is the benefit and cost related to changing pace shared alike between the various project actors?"

Or said with other words - how elastic are projects and how is cost and time related in building projects?

2. Material and methods

To answers this to questions we collected general project data, cost data and time related data from 54 construction projects that were constructed and completed in the period 2008-2013 in Norway. Dataset nr1 came from a large public organization that builds schools and other governmentally facilities on the behalf of the government. Dataset no 2 was provide from and project consulting firm, that also manage project on behalf of public project owner, and this set can be consider as subset of the larger dataset that is presented in figure 2. As part of the study was literature, review conducted. We searched after topic related to delays, time cost tread of and bottlenecks in construction project in database like SCOPUS (Elsevier) and Web of Science (ISI). The search was limited to the previous 30 years' period. High quality journals such as International Journal of Project Management (IJPM), Journal of Construction Management Economics (JCME), Engineering Construction and Architectural Management Journal (ECAMJ), Harvard Business Review (HBR), and Lean Management Journal has also been schecced for the same topics for the same periode.We also limted our serarch only to articels reltated to construction industry other industries has been skipped.

In order to answer the earlier mentioned research question, we conducted a study that consisted of three task – a literature review, harvesting of metadata of finished construction projects from different companies and harvesting of financial transaction over time from one company. The two data set was developed in two stages – data set one in the first stage of the study and data set two (smaller sample) in stage two. The first data set had a more general focus on project metadata such as project nature (private/public), project team composition, 5 key project milestones, economical figures, construction metrics (sq. meters, number of buildings) and some subjective assessments of logistical complexity and constructability. The data in sample one has been collected in a combination of guided self-reporting and interviews with project managers of the individual projects. All project data was normalized to year 2013, using table for increase in prices from Norway. For all of the project in sample one was actual time for execution collected, se figure no 2 Contract sum (million NOK, x-axis) vs construction time (months, y-axis).

The smaller <u>second data set</u> was developed in stage two of the study and consist of financial records and financial transactions for smaller sample of projects from study number 1. These were exported from the financial software used to manage the project economy. (see figure 3) In the second study was also data from planning stage included in the dataset. The sampling of projects was decided on availability in both of data sets. This study has been conducted in a quantitative and analytical tradition, drawing upon the analysis of quantitative project metrics for insight into the empirical relationships between time and cost[22]. The evidence is interpreted in an institutional economic understanding of project management. See e.g. Yung[23]. Focusing on the 'why' these trade-offs between cost and duration poses an interesting problem for a project manager rather than 'how' to deal with them (which is much more of an engineering problem).

3. Results – how does contact sum related to us of time to construction phase?

One of the purpose of the first study was to investigate if there was strong or a weak correlation between months of construction and contract sum that was awarded.

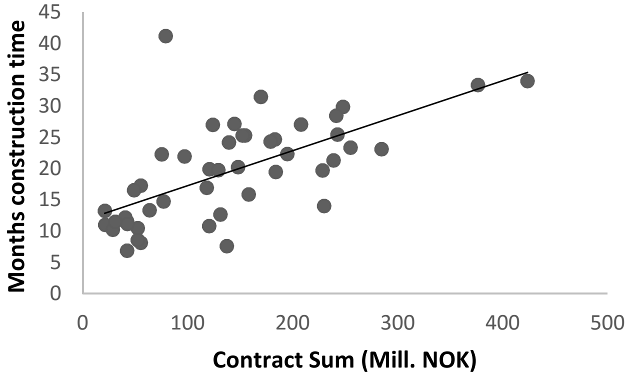

Figure 2 Contract sum (million NOK, x-axis) vs construction time (months, y-axis).

As we can see in Figure 2, the relationship between cost and construction duration is only moderately related (R^2=0.42). Simply put, beyond an initial 12-month duration (the y-intercept), each million in contract sum is equal to only 2 days of additional duration – indicating strongly that increasing productivity (i.e. turning over more cost per time, or producing more per time) is a common way to scale out a project.

In the second analyse, was smaller sample subset investigated. We study financial records from five project that was part of sample 1. We collected the data from the company's economic system. All the financial transaction was groped in to five categories, administration (projects owners cost), engineering, project management cost, construction and other (cost related to copying, art, insurance etc.) and then checked against time of us. The purpose of the second analyses was explore more in detail when in the project the spending takes place over the project duration, se figure no 3 Project costs as percentage of total broken down over the project duration (in months).

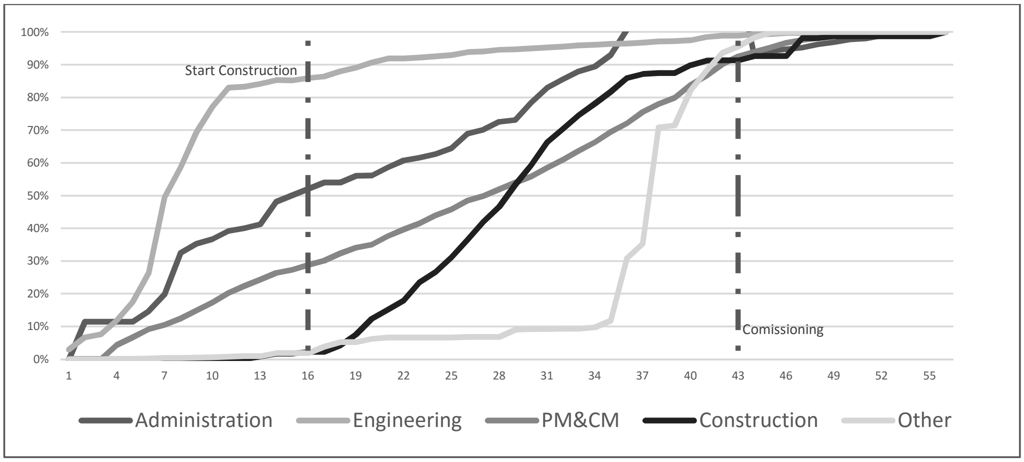

Figure 3 Project costs as percentage of total broken down over the project duration (in months)

In figure 3 (the smaller data set), can we clearly see the linear relationship between time and project and construction management, and similar for engineering. While the construction cost, which in general is procurement and labour, follows a more traditional s-shaped curve. The two vertical lines indicating start of construction and commissioning. In the detailed data, the average construction time is 20 months and 38 months of total duration (including engineering), with an average of 76% of the cost incurred during the construction. Dividing the cost accumulated for management between start and end of construction, each month in construction translates to 0.10-0.15% of the total cost. In addition, obvious time-dependent construction costs such as maintaining operations and rig costs accounts for an additional 0.20-0.25% per month. This means that a project delay would cost approximately 0.35% of the total contract sum just in time-dependent costs, not counting construction labour or materials.

4. Discussion time elasticity -who and what determines the correct project duration

In economic literature, price elasticity of demand is defined as a measure of how demand responds to price[cf. 20]. One could envision a similar concept that makes it possible to analyze how project respond to time economically and as a socio-technical system – and we suggest that concept should be called "time elasticity". In Figure 4 we have shown how various task-based tools along a pace axis intersect with the value of speeding/late delivery of the project. The vertical axis is related to the classical cost/time trade of – "the optimization problem"; the horizontal axis is related to value of Speeding Up or deliver late for the different stakeholders (Figure 4 Time elasticity).

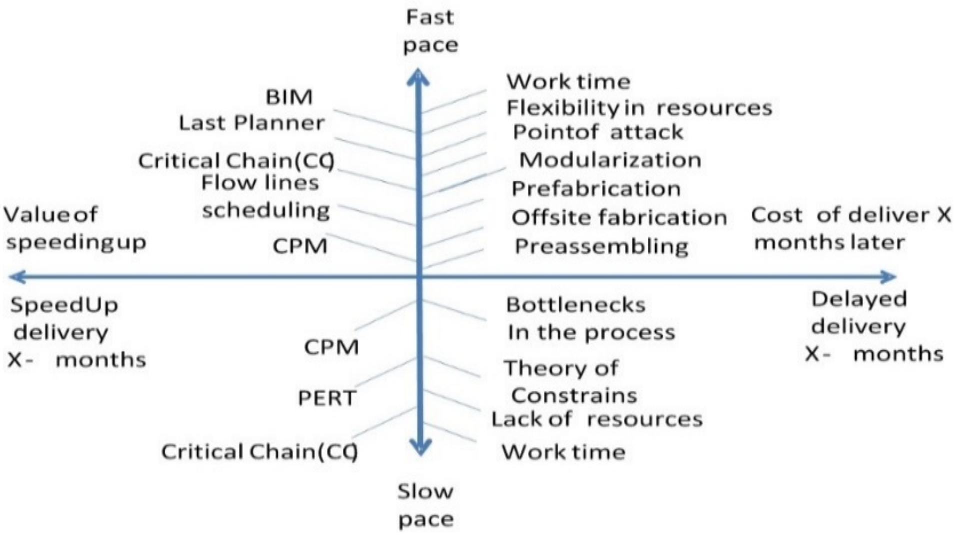

Figure 4 Time elasticity

In our data, we see that the value of speeding up or running late with the delivery of the project is not evenly distributed between the society, project owner, the project manager, the contractor or the employees that are doing the job in the project. We see that some stakeholders can get greater value of a high or low pace than others, and in many cases the project has to be completed considerably faster before the owner or society are willing to pay more for the delivery. In addition, the project must be considerably late before the penalties is awarded. In most of the cases is penalties just threaten with, or the contractor notified in early stage that they need time extension so that the penalties does not come to order. Relating back to the cost-time curve in Figure 1, one can observe the span of elasticity in the minimum of the curve – where the change in time does not change the cost.

What we have shown in the results (see Figures 2 and 3) is empirically the relationship between time and cost. The linear relationships in certain categories indicates that reduced project durations (with approximately the same quality) would reduce cost. While the correlation implies that the cost is only a minor influence on duration, the converse is also true – that larger projects (in cost) has a larger turnover per day. That is, they must also adopt a different level of resource and labour usage. For instance, working two shifts rather than one. Economically this also would indicate a higher operational equipment efficiency on capital equipment. If an average contractor signs for roughly 10% margin on projects, it would be an obvious point to attempt to finish as soon as possible – in order to move on to the next project if possible. For the owner, the total cost could be lower, not only moving towards an optimum on the cost/time curve described in Figure 1. In terms of projects delivering value – earlier delivery (or increased chance for on-time delivery) would also potentially mean earlier return on investment where the owner is waiting for the project to deliver.

When asking the overall question, how long should a project last – the initial plan attempts to mitigate owner needs with constructability and a reasonable risk profile (under an assumption that shorter duration may increase potential for overrun). However, when left to choose, if everything else is equal, the rational choice (economically) for most project managers would chose the longer duration. However, the construction industry being mostly project-based – most actors will move on to the next project after completion. So for a company, it would make sense to aim for short duration in order to deliver more projects in the same time (i.e. increasing the profits per time unit). A theoretical planned for three years under the assumption from Figure 1 – the cost-neutral time compression achieved by shortening the project duration from 3 to 2 years, would amount to a 4% overall cost reduction from time-dependent costs – but on a fixed-priced contract keep the profits the same. Correspondingly, from a value-for-the-owner perspective looking at Figure 2, there are examples of projects with roughly the same contract size (e.g. 120 Million) delivering at 10 months, 20 months and 27 months. The theory for compressing projects is well known, and was well developed in the early period of project management as a discipline in the 50s and 60s. Compressing time as such is a classic application of optimization of project processes (and the foundation of the task-based perspective on project management), but the lack of application of such techniques, or lack of incentives for doing so, even under economic rationality points to other sources of explanations for this behaviour. In line with neo-classical economy, the so called constrained maximization of benefits would in part explain the short-term choice of non-optimization of project schedule; the latter of Yung's[23] constraints, Risk and Time may in part describe why a project manager would seek a longer project duration. The economical rationality and the optimization of business would prefer the shorter, and rather seek to gain financially through pursuing additional projects in the same period of time at the same operational margin. Studies of critical success factors or project success stories will only seldom capture the true essence in this dichotomy, and similarly for project failure studies. The success of a single project fails to account for nuances faced by these actors in choosing, scheduling and executing their projects. Conclusion

The exploitation and conscious treatment of time elasticity is in many construction project an unused capacity. In many cases it is possible to make the project considerably faster, but it seems like the value of speeding up is considered differently between the stakeholders. The willingness to pay the same or more for and faster delivery is simply not there in many of the construction projects that we have studied. Some projects are more flexible than others in term of pace. Work schedule, resource access, how many points of attack, location, and construction technique (i.e. mostly task-related issues) may vary from project to project, but in most cases it is *the value of speeding up or slowing down* that define the limit of time. We have in this study highlighted, what in the task perspective seems to be an irrational "flaw" in project scheduling, may be in the organizational perspective a rational choice for mitigating time and cost. While the methods for process optimization, planning and control does not guarantee success, they may help avoid failures. However, theory relating to project duration and cost, depending on the viewpoint will often pull the project schedule in opposite directions. As seen from the empirical data presented, the end result is only a weak relationship between cost and duration. Further construction of project models that account for, *and balance*, the partly conflicting views of the various project roles and actors and how this causes an elasticity between cost and value - seems necessary to design, execute and deliver projects closer to an optimal duration. An optimal duration that maintains contractors' need for profitability as well as the owners' need to create value – at the right time. In our further research we will pursue qualitative studies of projects that may subjectively and/or objectively be considered as fast within their environments – in order to further understand under which circumstances where the cost is kept the same that the owner and contractor choose to push the envelope on duration and not.

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